Physics Flash

June 2019
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From left: Deputy Director of National Intelligence, Strategy and Engagement Corin R. Stone; Malcolm Boshier; Dana Berkeland; and Assistant Director of National Intelligence for Transformation and Innovation Pamela Duke.

Malcom Boshier and Dana Berkeland receive U.S. Intelligence Community 'Best Paper Award'

Malcolm Boshier (Applied Modern Physics, P-21) and Los Alamos National Laboratory guest scientist Dana Berkeland (Intelligence and Emerging Threats, GS-IET) have been recognized for the 2018 best paper among work published in the U.S. Intelligence Community's peer-reviewed science and technology journals. The scientists received the award at a recent ceremony at the Office of the Director of National Intelligence in Washington, D.C.

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"A survey of environmental magnetic field noise and mitigation techniques," which appears in the *Journal of Intelligence Community Research and Development* (JICRD), summarizes the measurements of background magnetic fields in a variety of environments at frequencies from near DC to hundreds of kilohertz. Boshier and Berkeland tabulate the magnitudes and frequencies of the noise sources and discuss the anticipated effects on signal collection. They describe various techniques to mitigate these noise sources during and after data collection, in particular looking at several data processing techniques.

JICRD is a multidisciplinary science and technology journal covering a wide range of topics affecting the intelligence landscape. Since its founding in the late 1990s, the journal has provided the U.S. Intelligence Community (IC) with a mechanism for peer review and a venue to securely publish sensitive research findings. Other sensitive IC journals include *GEOINT Science*, *Journal of Chemical and Biological Defense*, and the *Journal of Sensitive Cyber Research and Engineering*.

The work supports the Laboratory's Global Security mission area and its Science of Signatures science pillar.

Technical contact: Malcolm Boshier

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> *The summer students have been arriving and starting to work with us. ... My primary expectation is that the students have a safe and productive learning experience.*

From David's desk . . .

Welcome to summer, also known as student season. The summer students have been arriving and starting to work with us. I gave my student all-hands on 13 June in the Rosen Auditorium. I gave an overview of the Division and went over expectations for students and mentors. I will reiterate some of my expectations here. My primary expectation is that the students have a safe and productive learning experience. I expect that when they return to their institutions they will have positive things to say about working at LANL and possibly want to return, either for another summer or seeking permanent employment. This requires that the students work safely and securely, following LANL's procedures. The students should have a questioning attitude. New eyes on a problem or process can lead to better and/or safer ways to accomplish the task at hand. The students need to understand that they have a duty to pause work if anything seems amiss. The mentors need to engage frequently with their students, making sure that they are available to answer questions, help the students move forward, and making sure that they are working safely and securely. If the mentor is going to be away for an off-site meeting or vacation, he or she needs to ensure that the student gets adequate supervision during this time. Group management needs to have a good understanding of the progress of their students. I hope you all have a wonderful summer.

I spent time as a facilitator at the SAFE Academy for Excellence (SAFE) at Argonne National Laboratory. "SAFE is a two-day immersion, leadership development workshop that features presentations, learning activities, and application through scenario practice. This program is a collaboration among a number of the national laboratories. SAFE has developed a set of 8 guiding principles:

1. Everyone is personally responsible for ensuring safe operations;
2. All staff value the safety legacy they create in their discipline;
3. Staff raise safety concerns because trust permeates the organization;
4. Cutting-edge science requires cutting-edge safety;
5. A questioning attitude is cultivated;
6. Learning never stops;
7. Hazards are identified and evaluated for every task, every time;
8. A healthy respect is maintained for what can go wrong AND What Must Go Right.

These principles must be applied through both a psychological and physical lens. Every voice matters; inclusion, acknowledgement, and appreciation for all perspectives is necessary and beneficial, as well as considerate." The program is currently focused on first-line managers, though I expect that it will become available to staff who are considering management opportunities in the future.

The reason that I chose to do SAFE at Argonne is that it gave me an opportunity to spend a day at Fermilab where Physics Division participates in a number of experiments. E906 (Seaquest) has been completed and data is being analyzed. E1039 (Spinquest) is being installed and the hope is to begin commissioning later this year. The MiniBoone detector has been taking data for many years and was highlighted in the previous *Physics Flash*. We are participating in the Short-Baseline Neutrino Program, which involves three detectors at the neutrino campus, two of which are under construction. I am always happy to see the places where we perform our research activities and further understand the research that we are doing. I had never been to Fermilab before and even got to see the bison, including a number of calves.

I hope that everyone has a safe, secure, and productive summer, taking time to enjoy the non-work sides of your lives.

Physics Division Leader David Meyerhofer

New cross-section measurement aids understanding of cosmic nuclei synthesis

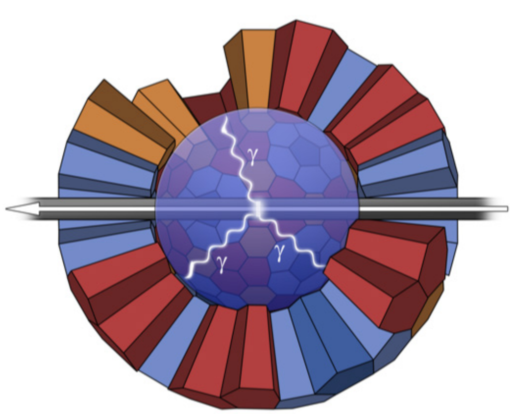
Recent neutron-capture cross-section measurements of copper isotopes performed at the Los Alamos Neutron Science Center (LANSCE) using DANCE, the Detector for Advanced Neutron Capture Experiments, have improved understanding of how nuclei are synthesized in the cosmos.

A team of researchers from Los Alamos and Charles University of Prague recently published its results in *Physical Review C*. The work was performed as part of a Director's Postdoctoral Fellowship by recently converted staff member Christopher Prokop (LANSCE Weapons Physics, P-27).

DANCE, located on flight path 14 of the Lujan Center at LANSCE, is a gamma-ray calorimeter composed of 160 barium fluoride crystals. Its large angular coverage and high intrinsic efficiency make DANCE an ideal instrument to perform measurements on a wide variety of stable and near-stable isotopes applicable to several programs spanning national security, nuclear energy, nuclear forensics, and nuclear astrophysics.

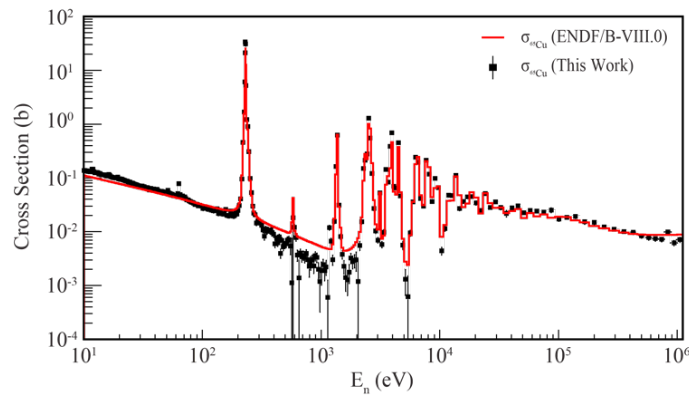
Elements heavier than iron are produced via neutron-capture reactions via two predominant processes characterized by the timescales over which they occur. The rapid neutron capture process (*r* process) proceeds far away from stability over short (~ minutes) timescales and involves many exotic isotopes. The slow neutron capture process (*s* process) occurs over much longer (many thousands of years) timescales and proceeds along the neutron-rich edge of the valley of beta stability.

In the analysis of solar abundances, the yield of the *s* process is often used to infer the contribution of the *r* process and other novel nucleosynthesis mechanisms. As such it is important to understand the input nuclear physics governing the *s* process. The reaction flow of the *s* process is dictated by the neutron-capture cross sections and the beta-decay half-lives of the participating nuclei. Along the path of the *s* process are a few key nuclei that have a large impact on this reaction flow and thus the nucleosynthesis yields from the *s* process. One such isotope is ^{65}Cu, where discrepancies in existing neutron-capture cross-section measurements can introduce 10–20 % uncertainties for the *s*-process yield for a substantial fraction of isotopes with mass number $60 > A < 90$.



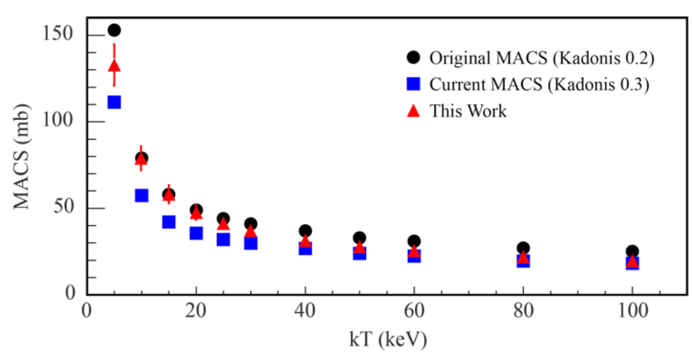
An illustrated cutaway of DANCE showing the instrument's geometry, with gamma-rays originating from interactions at the sample position at the center.

In this study a ~ 210-mg sample of isotopically enriched ^{65}Cu was obtained from the National Isotope Development Center at Oak Ridge National Laboratory. The energy-differential cross section obtained from this work is shown as black squares in the figure below. In red is an overlay of the ENDF/B-VIII.0 cross section modified for the response of the neutron production target and moderator assembly.



Shown in black squares is the measured energy-differential neutron-capture cross section on ^{65}Cu. Shown in red is the ENDF/B-VIII.0 cross section adjusted for the response of the neutron production target and moderator assembly.

The figure below shows a comparison of Maxwellian-averaged cross sections (MACS) between this work (red triangles) and prior measurements (black circles and blue squares). The present work impacts both the magnitude and energy dependence of the ^{65}Cu MACS values.



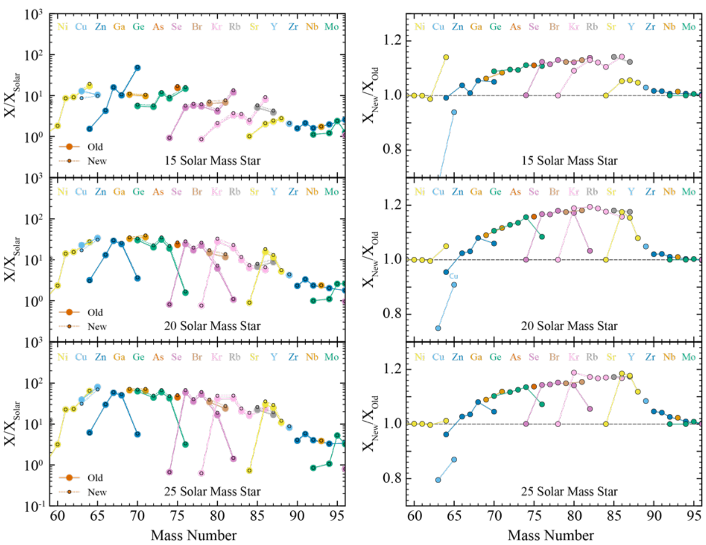
A comparison of the Maxwellian-averaged cross sections from this work (red triangles) with previous measurements (black circles and blue squares).

The impact of these new MACS values for ^{65}Cu, combined with additional recent DANCE measurements on ^{63}Cu and ^{63}Ni, was investigated. Massive 15, 20, and 25 solar mass stars were evolved from the main sequence to the

continued on next page

New cross-section measurement cont.

pre-supernova stage using both the currently accepted cross sections as well as the updated values. In each case unstable isotopes were allowed to decay for 10^{16} seconds and only the portion ejected in the supernova was considered. Below are the results of these models. Panels on the left show the composition of the stars at the pre-supernova stage as a ratio to solar abundance. Panels on the right show the relative differences in composition of the stars as a ratio of abundances obtained with updated cross sections compared to the currently accepted values. The updated cross sections affect the abundances of more than a dozen isotopes above the 10% level for all three stellar masses.



Results of stellar models at the pre-supernova stage. Unstable isotopes have been allowed to decay for 10^{16} s. The left panel shows the composition relative to the solar abundance distribution while the right panel shows the relative difference in composition when the updated ^{63}Cu, ^{65}Cu, and ^{63}Ni cross sections are used compared to the previously accepted values.

This work supports the Lab's Nuclear and Particle Futures science pillar, with particular impact on the goals of Cosmic Explosions: Origins to Ashes and the Origin, Evolution, and Properties of Atomic Nuclei. NNSA/OES and the Lab's Laboratory Directed Research and Development program provided support for the LANL investigators. The ^{65}Cu isotopes used in this research were supplied by the US DOE Office of Science by the Isotope Program in the Office of Nuclear Physics.

Los Alamos researchers are C. J. Prokop, A. Couture, S. Mosby, and J. L. Ullman (P-27), S. Jones (Eulerian Codes, XCP-2), G. Rusev (Nuclear and Radiochemistry, C-NR).

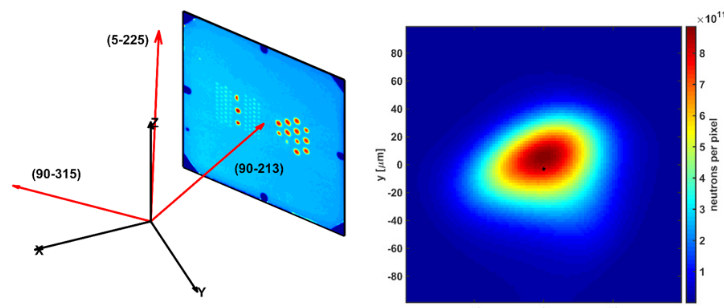
Reference: "Measurement of the ^{65}Cu(n,γ) cross section using the Detector for Advanced Neutron Capture Experiments at LANL," *Physical Review C* 99, (2019).

Technical contact: C. J. Prokop

New Los Alamos instrument measures tomographic images of burning plasma

The Laboratory's Advanced Imaging team has installed a third neutron imaging line-of-sight for imaging inertial confinement fusion (ICF) implosions at the National Ignition Facility (NIF). This technically challenging feat now allows for three-dimensional (3D) tomography of burning fuel during the thermonuclear burning phase of the implosions—an exciting novel diagnostic to visualize performance-limiting asymmetries and hydrodynamic mix in ICF.

The team successfully took its first data using the new line-of-sight in December. The added detector is based on passive-image plate technology and a 20-cm-long multi-aperture pinhole array constructed from tungsten and gold leaf. Eighty-seven pinholes and 3 penumbrae record neutron images, while the second half of the aperture includes 12 penumbrae to record low-yield neutron images and will be used in the future to record gamma images using an active detector system under design. Meticulous metrology measurements of the aperture assembly made by Engineering Materials (MST-7) allow for high-resolution reconstruction of the neutron source.



The first image plate data recorded on the new line-of-sight during a qualification shot at NIF in December (left) shown in the coordinate system indicating the other two Los Alamos lines-of-sight. In the successful shot, all pinholes were aligned and usable for reconstruction, as seen in the reconstruction of the neutron image (right).

Inertial confinement fusion is based on the symmetric compression of deuterium-tritium fuel capsules through ablation drive to reach temperatures and pressures necessary to produce a central burn volume undergoing fusion. Ideally, the burn then propagates through the remaining cold fuel to reach ignition. So far, ignition has not been achieved at the world's most powerful ICF facility—the NIF. It is believed that strong asymmetries in the compression and hydrodynamic mixing of the fuel shell material into the central fuel region are the key performance limitations.[1] The ability to diagnose them is critical to work toward improvements. Neutron imaging[2] is an effective diagnostic tool for measuring the size and shape of the neutron producing region during the stagnation phase. Combined with x-ray imaging

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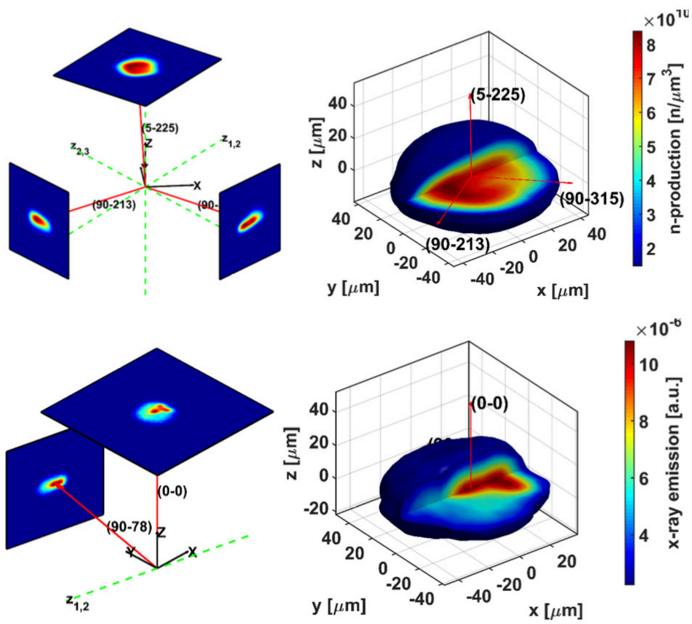
New Los Alamos instrument cont.

measurements, also made by Los Alamos, the team's powerful reconstruction algorithms can now diagnose mix as well.

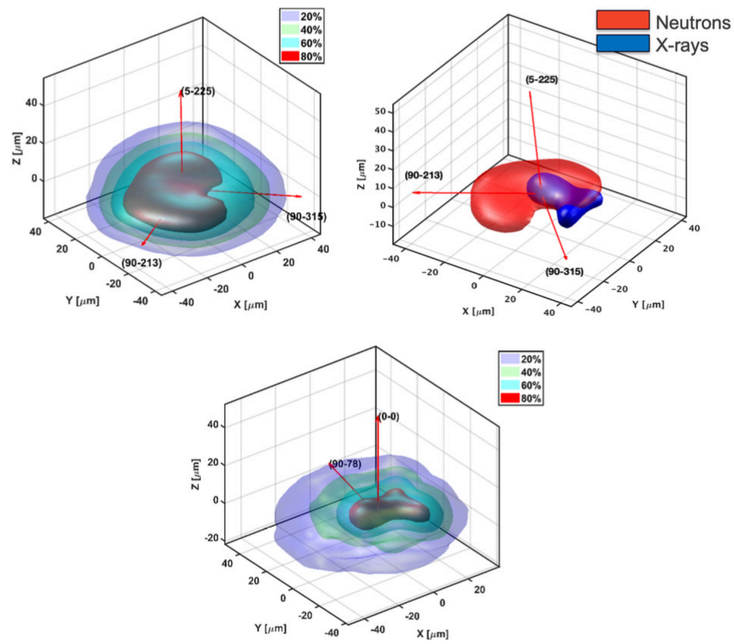
The Los Alamos team now operates three neutron imaging lines-of-sight at NIF, two equatorial views and one polar, allowing for 3D tomography of the fusion burn volume [3,4]. This capability was used to perform a 3D reconstruction of the neutron volume production using powerful 3D algorithms developed by the team in anticipation of the new detector. The figure below shows the tomography algorithm applied to the 3D neutron imaging data as well as existing x-ray imaging diagnostics.



Reconstructed 3D neutron volume production (top) and x-ray emission (bottom) in the preliminary analysis of a recent NIF shot (N190120-001).

The next figure shows the 3D reconstructed regions of high neutron and high x-ray emission in the same coordinate system. It can be seen that the neutron emission is dampened on the side of high x-ray emission. In this breakthrough, the team conclusively demonstrated that regions of high x-ray emission do not exhibit neutron emission during stagnation—showing performance-limiting mix of high Z material into the fuel in 3D for the first time.

Researchers include Petr Volegov, Christopher Danly, Verena Geppert-Kleinrath, Frank Merrill, Carl Wilde (all Neutron Science and Technology, P-23), Valerie Fatherley, Steve Batha, Michael Springstead, John Oertel (Plasma Physics, P-24), Derek Schmidt, Lynn Goodwin, John Martinez (Engineered Materials, MST-7), Justin Jorgenson (Process Automation and Control, E-3), Doug Wilson (Plasma Theory and Applications, XCP-6), and David Fittinghoff, Gary Grim, Robin Hibbard, Cory Waltz, Sebastien Le Pape, Arthur Pak, Laurent Divol, Laura Berzak Hopkins (Lawrence Livermore National Laboratory).

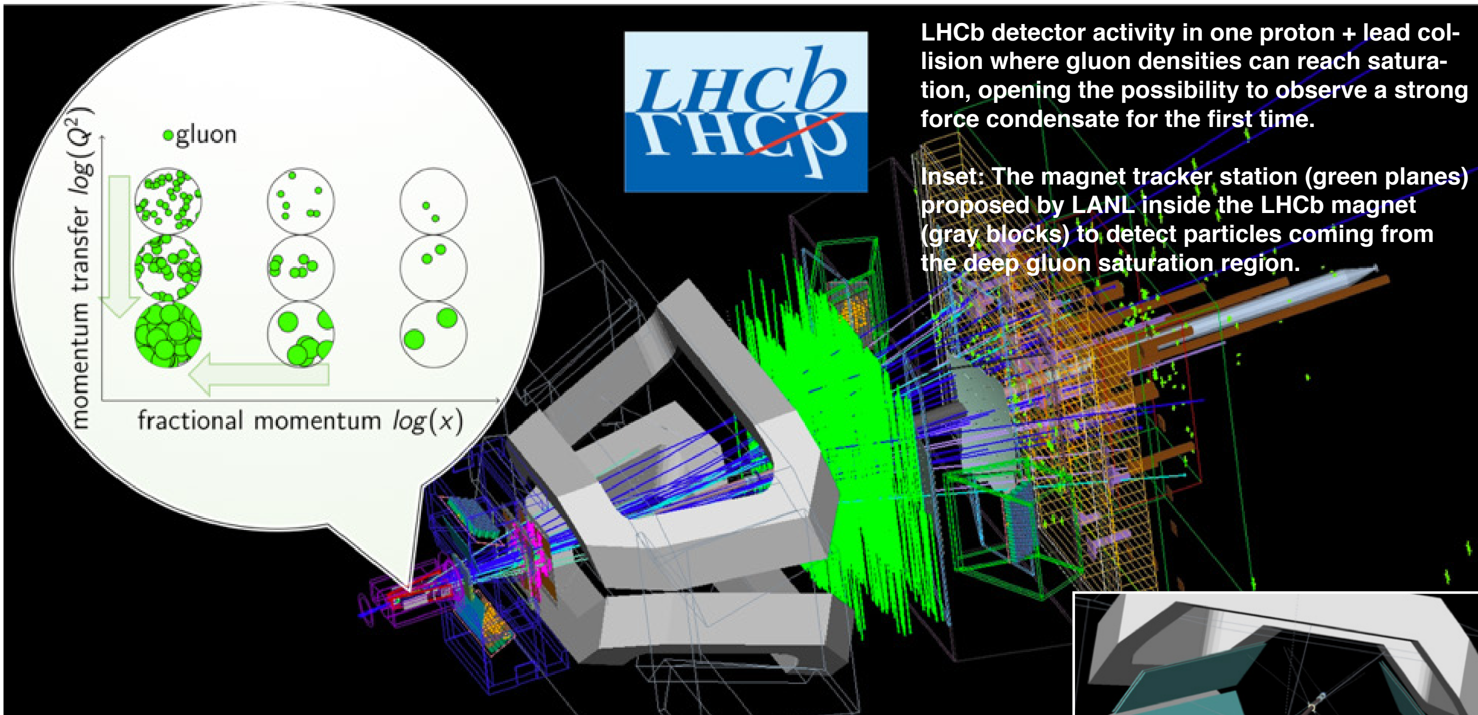


Left: neutron volume production iso-surfaces. Right: x-ray emission iso-surfaces. Center: combined iso-surfaces of neutron (red) and x-ray (blue) high emission area (80% of maximum). Performance-limiting mix of high Z material into the fusion plasma is conclusively seen for the first time in N190120-001. 3D tomography of the burn volume and the application of Los Alamos's 3D algorithms to x-ray images allow for the unique view.

This work was funded by NNSA Science Campaigns under the ICF Program (LANL Program Manager, John Kline, ESP). The work supports the Laboratory's Stock Stewardship mission and Nuclear and Particle Futures science pillar.

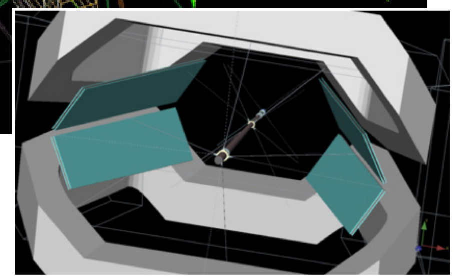
Technical contact: Petr Volegov

[1] F. E. Merrill et al. "The neutron imaging diagnostic at NIF," *Review of Scientific Instruments* 83.10 (2012).
[2] T. Ma et al., "Onset of hydrodynamic mix in high-velocity, highly compressed inertial confinement fusion implosions," *Physical Review Letters* 111 (2013).
[3] P. L. Volegov et al. "On three-dimensional reconstruction of a neutron/x-ray source from very few two-dimensional projections," *Journal of Applied Physics* 118.20 (2015).
[4] P. L. Volegov et al. "Three-dimensional reconstruction of neutron, gamma-ray, and x-ray sources using spherical harmonic decomposition," *Journal of Applied Physics* 122.17 (2017).



LHCb detector activity in one proton + lead collision where gluon densities can reach saturation, opening the possibility to observe a strong force condensate for the first time.

Inset: The magnet tracker station (green planes) proposed by LANL inside the LHCb magnet (gray blocks) to detect particles coming from the deep gluon saturation region.



Los Alamos joins CERN's LHCb team as full member

The Institution Board of the Large Hadron Collider beauty (LHCb) experiment recently recognized Los Alamos as a full member of the collaboration with voting rights to help decide the future of the experiment. The new status comes as Los Alamos scientists lead an effort to design and install new detectors to look for gluon saturation.

This is the first time Los Alamos has been a voting member of a Large Hadron Collider experiment. The LHCb collaboration expects that the high-energy nuclear physics team at Los Alamos will co-lead and boost its incipient nuclear physics program. The collaboration includes 79 organizations. LHCb has been operating since 2010.

The Large Hadron Collider, located near Geneva, Switzerland, is the world's largest and most powerful accelerator. As one of seven particle physics detector experiments running at the Large Hadron Collider, the LHCb experiment aims to understand why the universe has far more matter than antimatter. This is accomplished by studying the difference between a subatomic particle called the beauty quark (also known as the bottom quark) and its antimatter twin, as well as studying the force that acts upon quarks to bind them, called a gluon, which is a massless subatomic particle.

The LANL team found that the LHCb experiment has unique capabilities to examine gluon saturation—the hypothesized process in which gluons start to overlap and fuse. The Standard Model predicts gluon saturation will occur when there is a large number of gluons in limited space; however, it is still unknown whether this occurs naturally. The gluon saturation regime can form a strong force condensate, like other condensates found in cold atoms, but regulated by electromagnetic forces.

Previous attempts at seeing the gluon saturation process have been complicated by unintended nuclear effects. The LHCb can search for gluon saturation through means that are not sensitive to nuclear effects; however, this requires new detectors, which LANL will contribute. Previously, as the products of the beam collision traveled through the LHCb magnet, soft particles like the ones coming from saturated gluons could not reach the downstream tracking detectors, instead hitting the inner walls of the magnet. The new detectors will mitigate the issues. With expertise in high-energy nuclear physics as well as detector design and engineering, Los Alamos has been working on the design and prototyping of a particle tracking detector to measure these soft particles. After a thorough review process, LHCb has recommended the installation of a detector prototype and a pathway for full construction in 2025.

The work supports the Laboratory's fundamental science mission area and its Nuclear and Particle Futures science pillar by studying subatomic particles and their contribution to the universe and by developing the expertise and capabilities required for the Lab's national security mission.

Researchers: Jana Crkovska, Cesar da Silva, Matt Durham, Eliane Epple, Berenice Garcia, Hubert van Hecke, Gerd Kunde (Subatomic Physics, P-25).

Technical contact: Cesar da Silva

Mandie Gehring recognized with distinguished young alumni award

Mandie Gehring (Neutron Science and Technology, P-23) was recognized by her undergraduate alma mater, Rose-Hulman Institute of Technology (RHIT) in Indiana, with a 2018 Distinguished Young Alumni Award. The award identifies alumni who have graduated within the last 10 years who have pursued notable endeavors in career achievement, continued education, community service and/or commitment to their alma mater.

Gehring, National Security Science team leader in P-23, is the recipient of two NNSA Defense Programs Awards of Excellence and a LANL Large Team Distinguished Performance Award. She is involved with the RHIT alumni network, including co-organizing her class's 10-year reunion, and in Los Alamos is active with her church's outreach efforts.

Gehring has also been selected to participate in Los Alamos National Laboratory's MEDAL (for Mid/early-career Deter-detect-prevent Advanced Leadership) program. Gehring and the 2019 cohort will visit the nation's capitol to meet with members of DOE NNSA and non-DOE agencies, including the Department of Defense, the White House, Congress, and the State Department. The program also prepares participants with readings, monthly roundtables, and two Washington D.C. primers: a series of presentations to familiarize participants with a wide range of relevant topics on nuclear weapons, nonproliferation, counterproliferation, counterterrorism, and intelligence.

Technical contact: Mandie Gehring

Celebrating service

Congratulations to the following Physics Division employees recently celebrating service anniversaries:

John Ullman, P-27	40 years
David Montgomery, P-24	35 years
Scott Currie, P-25	30 years
Bill Waganaar, P-27	30 years
John Oertel, P-24	25 years
Gerri Barela, P-DO	15 years
Kirk Flippo, P-24	15 years

HeadsUP!

Distracted driving awareness

Every day, at least 9 Americans die and 100 are injured in distracted driving crashes.

Visual driving distractions cause you to take your eyes off the road. These distractions include
- checking your GPS or navigation system;
- looking to see what song is playing on the radio;
- searching for mirror or temperature controls; and
- looking for lost items on the floor of your vehicle.

Manual distractions are distractions that cause you to take your hands off of the wheel. These include
- eating, drinking, or smoking;
- checking your phone;
- adjusting the radio; and
- setting a destination in your vehicle's in-dash navigation system.

Cognitive distractions take your focus and concentration away from driving. These include
- talking to passengers in the vehicle;
- encountering road rage;
- driving under the influence of drugs or alcohol; and
- driving while drowsy or fatigued.

PhysicsFlash

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To submit news items or for more information, contact Karen Kippen, ALDPS Communications, at 505-606-1822, or aldps-comm@lanl.gov.

For past issues, see www.lanl.gov/orgs/p/flash_files/flash.shtml.

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